APPLICATION FOR PATENT

Title: Gravel Pack Crossover Tool with Single Position Multi-function Capability

Inventor: Thomas G. Corbett

FIELD OF THE INVENTION

[0001] The field of this invention is crossover tools for gravel packing a screen downhole and more particularly to crossover tools that permit the squeezing, circulating and reversing out with the tool in the same position with respect to a downhole packer.

BACKGROUND OF THE INVENTION

[0002] Figures 1-6 illustrate the prior art crossover tool in a typical gravel packing operation. The wellbore **10** receives a running string and setting tool shown schematically as **12**. A packer **14** sealingly accepts the string and setting tool **12**. A ball seat **16** is located in the crossover tool **18** just above gravel pack port **20**. Screen extension **22** is attached to packer **14** and has ports **24** to permit gravel access to annulus **26**. Screen extension **22** has a seal bore **28** through which a wash pipe **30** extends in sealing contact for run in, shown in Figure 1, due to contact of seals **32**. A flapper **34** allows uphole flow in wash pipe **30** and prevents downhole flow. Return ports **36** are in the seal bore **38** of the packer **14** and are closed due to the position of seals **40** that straddle return ports **36** in seal bore **38**. Screen extension **22** has a support surface **42** that can engage tabs **44** to pinpoint the circulation position of Figure 4.

[0003] To set the packer **14**, the assembly is run into position, as shown in Figure 1 and a ball **46** is dropped onto ball seat **16**. Ultimately, after the packer is set, the ball **46** is blown through ball seat **16** or the ball and the seat move together after a shear pin (not shown) is broken and the assembly lands in recess **48** (see Figure 3). One of the problems with this layout is that if the formation is under sub-hydrostatic pressure, such sub-hydrostatic pressure communicates with the underside of ball **46** on seat **16** and limits the amount of pressure that can be applied from above, shown schematically as arrows **50**,

before breaking a shear pin on the ball seat **16**. This can reduce the available pressure to set the packer **14** because the sub-hydrostatic pressure on the underside of ball **46** acts equivalently to applied pressure from above, represented by arrows **50**. Yet another drawback of this arrangement is that when the packer **14** makes contact with the wellbore **10** and the passage through its seal bore **38** is obstructed, the liquid column above the packer **14** can no longer exert pressure on the formation. This can result in portions of the formation breaking off into the wellbore and potentially obstructing it. The present invention addresses these problems by repositioning the ball seat **16'** and insuring that the seal bore **38'** is not closed by the crossover tool **18'** during setting of the packer.

[0004] Continuing now with the prior technique, after the packer **14** is set, the ball **46** and the seat **16** are blown into recess **48**. The set of the packer can be tested by applying pressure to annulus **54**. Furthermore, gravel slurry or fluid represented by arrows **52** can be squeezed into the formation adjacent to the screens (not shown) as illustrated in Figure 3. The fluid represented by arrow **52** flows through the crossover tool **18** to exit the gravel pack port **20** and then flows through ports **24** in screen extension **22** into the annulus **26** around the outside of the screens (not shown). Returns are blocked off because the return ports **36** are sealingly positioned in seal bore **38** of the packer **14** by virtue of straddle seals **40**. Any leakage past packer **14** will be seen as a pressure rise in annulus **54**.

[0005] The next step is circulation, shown in Figure 4. Here the gravel slurry represented by arrows **56** passes through the crossover **18** through gravel pack ports **20**. It then passes through ports **24** in screen extension **22** and into the annulus **26**. The gravel remains behind in annulus **26** around the screens (not shown) and the carrier fluid, represented by arrows **58**, passes through the screens and opens flapper **34**. It should be noted that the crossover tool **18** has been raised slightly for this operation to expose return ports **36** into annulus **54** above packer **14**. The carrier fluid **58** passes the flapper **34** and exits the return ports **36** and goes to the surface through annulus **54**. Lug **44** rests on support surface **42** to allow the crew at the surface to know that the proper position for circulation has been reached.

[0006] In the next step, called evacuation, the excess gravel that is in the annulus **70** between the screen extension **22** and the crossover tool **18** needs to be reversed out so that the crossover tool **18** will not stick in the packer seal bore **38** when the crossover tool **18** is lifted out. To do this, the crossover tool **18** has to be lifted just enough to get the evacuation ports **60** out of seal bore **28**. Evacuation flow, represented by arrows **62** enters return ports **36** and is stopped by closed flapper **34**. The only exit is evacuation ports **60** and back into gravel pack port **20** and back to the surface through the string and setting tool **12**. The problem here is that the intermediate position for reversing gravel out from below the packer **14** is difficult to find from the surface. Due to the string **12** being long and loaded with gravel at this point, the string is subject to stretch. The surface personnel for that reason are prone to wittingly or unwittingly skip this step and pull the crossover tool **18** up too high into the alternate reverse position shown in Figure 6. In the Figure 6 position, the evacuation ports **60** are closed in seal bore **38** of packer **14** and gravel pack port **20** is now above packer **14** in annulus **54**. Arrows **64** show how the reversing flow clears out the string **12** above packer **14**.

[0007] The problem with skipping the evacuation step is that the excess gravel in the annulus **70** below packer **14** may cause the crossover tool **18** to stick in seal bore **38** as the crossover tool **18** is raised to accomplish the reverse step shown in Figure 6 or later when crossover tool **18** removal is attempted. The present invention allows the evacuation step to occur without having to reposition the crossover tool **18** with respect to the packer **14**. This is accomplished by the addition of check valves **66** in relocated evacuation ports **60'**. Additionally, the steps of squeezing, circulating and reversing out can be accomplished with the tool in the same position of support from the packer **14'**. The present invention will be more readily appreciated by those skilled in the art from a review of the description of the preferred embodiment and the claims that appear below.

SUMMARY OF THE INVENTION

[0008] A gravel packing method and apparatus are described where to set the packer; a ball is dropped to a seat that it isolated from the effects of formation pressures when trying to set the packer. This is accomplished by isolation of the gravel pack outlet

port when setting the packer and locating the ball seat in a position where the effects of formation pressure are irrelevant. Additionally, by positioning the evacuation ports above a seal bore in the screen extension during circulation to deposit gravel and further putting check valves in the evacuation ports, the evacuation step after circulation can be accomplished without having to reposition the crossover. The crossover tool is supported from the packer and movement of the crossover tool away and back to the support from the packer operates a valve to allow squeezing when the valve is closed and circulating and reversing out when the valve is open.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Figure 1 is the run in position of the prior art method of gravel packing;

[0010] Figure 2 is the view of Figure 1 in the packer setting position;

[0011] Figure 3 is the view of Figure 2 in the packer test and squeeze position

[0012] Figure 4 is the view of Figure 3 in the circulate to deposit gravel position;

[0013] Figure 5 is the view of Figure 4 in the evacuation position;

[0014] Figure 6 is the view of Figure 5 in the alternate reverse position;

[0015] Figure 7 is the present invention in the run in position;

[0016] Figure 8 is the view of Figure 7 in the packer set position;

[0017] Figure 9 shows the packer test position;

[0018] Figure 10 is the view of Figure 7 in the circulate to deposit gravel position;

[0019] Figure 11 is the view of Figure 10 in the evacuation position;

[0020] Figure 12 is the view of Figure 7 in the squeeze position; and

[0021] Figure 13 is the view of Figure 11 in the alternate reverse position.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0022] In the run in position of Figure 7, the seal bore **38'** has a clearance **68** around the crossover tool **18'**. The ball seat **16'** is located below gravel pack port **20'**. During run in and setting of the packer **14'**, the gravel pack port **20'** is sealed in seal bore **28'** by virtue of seals **32'**. As shown in Figure 8, when the ball **46'** lands on seat **16'** it will not go any lower. Thus exposure to sub-hydrostatic formation pressures below ball **46'** will not affect the setting of packer **14'**. This is because there is no longer any need to shear out the seat **16'** due to its location below gravel pack port **20'**. An upward shift of the crossover tool **18'** will position gravel pack port **20'** out and above seal bore **28'**, as illustrated in Figure 10, so that gravel slurry **56'** can be pumped down string **12'** and into annulus **26'** with returns **58'** coming through flapper **34'** and into annulus **54'** by way of return ports **36'**. It should be noted that during circulation, the evacuation ports **60'** are above the seal bore **28'** but internal pressure in wash pipe **30'** is prevented from exiting the wash pipe **30'** through the evacuation ports **60'** by the presence of check valves **66**. This is because the pressure in annular space **70'** exceeds the pressure within the wash pipe **30'** forcing the valve member **72** against its seat **74** with the assistance of spring **76**.

[0023] The evacuation step shown in Figure 11 can be accomplished without having to raise the crossover tool **18'**. Instead, the reverse flow indicated by arrows **62'** goes down annulus **54'**, through return ports **36'**, and out through check valves **66**. This time the pressure inside wash pipe **30'** is greater than the pressure in annular space **70'** and the valve members **72** are pushed against the bias of springs **76** to move away from their respective seats **74**. The flow continues to gravel pack ports **20'** and up to the surface through the string **12'**. The fact that the position of the crossover tool **18'** does not need to be changed after the circulation of the gravel into position, insures that the evacuation step will actually be executed. Insuring that the evacuation step is accomplished minimizes if not eliminates the risk of sticking the crossover tool **18'** in the seal bore **38'** of packer **14'** due to remaining gravel in the annulus **70'** below the packer **14'** as the crossover tool **18'** is being lifted for the reverse step of Figure 13 or during its total removal at the conclusion of the gravel packing operation.

[0024] Those skilled in the art will readily appreciate the advantages of the present invention. First, since the ball seat **16'** is never sheared out after setting the packer **14'** because the ball seat **16'** is already below the gravel pack outlet **20'**, the effects of sub-hydrostatic formation pressure on the packer setting operation go away. This is because there is no shear pin to break prematurely before the packer **14'** is set due to sub-hydrostatic pressure on the underside of a seated ball **46'**, as can be seen in Figure 8.

[0025] The packer bore **38'** has a clearance around the crossover tool **18'** when the packer is set. Thus, the liquid column to the surface is always acting on the formation even as the packer makes contact with the wellbore **10'**. Having this column of fluid to exert pressure on the formation prevents cave-in of the wellbore as the pressure prevents pieces of the formation from breaking off into the wellbore.

[0026] The crossover tool **18'** does not need to be moved between circulation shown in Figure 10 and evacuation, shown in Figure 11. This insures proper removal of gravel from annulus **70'** before trying to move the crossover tool **18'**. The chance of sticking the crossover tool **18'** in the seal bore **38'** is reduced if not eliminated.

[0027] In the packer setting position of Figure 8, the gravel pack ports **20'** are sealed in seal bore **28'**. To test the set packer, the crossover tool **18'** is lifted slightly to expose the gravel pack port **20'** and to put seal **104** into seal bore **38'** of the packer **14'**. Seal **104** isolates return ports **36'** from above and the set of packer **14'** can be tested by applying pressure to annulus **54'**. This position is shown in Figure 9 and is obtained when collet support **44'** lands on support **42'**. To get from the test packer position of Figure 9 to the circulate position of Figure 10, the crossover tool **18'** is raised to get the collapsible supports **100** through seal bore **38'** so that they become supported on the packer **14'** as shown in Figure 10. The act of raising the crossover tool **18'** works to operate valve **102** from the open position of Figure 10 to the closed position in Figure 13. Squeezing can now occur as the closed valve **102** prevents the pumped fluid **52'** from returning through the wash pipe **30'**. Valve **102** can be one of a variety of designs such as a ball, a plug, or a sliding sleeve, to mention a few examples. The operating mechanism for valve **102** can

be a j-slot or other known techniques responsive to movement. Once in the Figure 12 position for a squeeze job, the crossover can be placed into the circulate position by simply picking up supports **100** off of packer **14'** and setting right back down again to the same position. The up and back down movement results in opening of valve **102** as shown in Figure 10. Circulation is now possible as returns open flapper **34'** and flow through valve **102** and through the crossover and out to ports **36'** and up to the surface through annulus **54'**. In the reverse operation, without movement of the crossover tool **18'** flow **62'** enters ports **36'** and pushes open check valves **66** because no flow can go through the flapper **34'**. As a result the flow enters annulus **70'** and cleans it out on the way back uphole through the tubing **12'**. After this reverse operation is accomplished, the crossover tool is picked up to close valve **102** while getting ports **20'** above seal bore **38'** while check valves **66** are effectively isolated in seal bore **38'**. In this position flow down annulus **54'** goes through ports **20'** to take any residual gravel to the surface through the tubing **12'**. Closing valve **102** is not mandatory but can happen coincidentally because the crossover **18'** is lifted to the Figure 13 position. Additionally, in the Figure 13 position, the check valves **66** can be in the seal bore **38'** or above it.

[0028] Those skilled in the art will appreciate that the tool of the present invention allows the crossover tool **18'** to remain in the same position with ports **36'** in fluid communication with annulus **54'** above the packer **14'** while the squeeze operation takes place. Then by shifting the crossover tool **18'** up and down to the same position as it was in during the squeezing operation, the circulating for gravel deposition can take place as well as reversing out. The initial reversing out requires no movement of the crossover tool **18'**. The initial reversing out occurs with gravel outlet **20'** still below the seal bore **38'** in the packer **14'** and allows a thorough removal of any remaining gravel in annulus **70'** before any attempt is made to pick up the crossover tool **18'**. Doing the initial reverse, as shown in Figure 11, removes or minimizes the risk of sticking the crossover tool **18'** in the seal bore **38'**. It is only after the annular space **70'** is reversed out that the crossover tool **18'** is picked up to get the gravel outlets **20'** above the packer **14'** for what is shown in Figure 13 as the alternate reverse step. The alternate reverse step in Figure 13 is optional in that the entire contents of tubing **12'** can be reverse circulated out of the well in the reverse position as shown in Figure 11. It should be noted that

shifting the crossover tool up and then back down after a squeeze operation shown in Figure 12 results in opening of valve **102** to make circulation possible. Alternatively, valve **102** can be run in open if there is no squeeze step called for in the completion plan. Returns are possible in the circulation mode of Figure 10 because valve **102** is open and flow up the wash pipe **30'** opens the flapper **34'**. On the other hand, when the flow direction is reversed after circulation and deposition of the gravel, flow down the wash pipe **30'** is stopped by flapper **34'** and check valves **66** let flow pass into annular space **70'** to return to the surface through gravel ports **20'** and then through tubing **12'**.

[0029] The foregoing disclosure and description of the invention are illustrative and explanatory thereof, and various changes in the size, shape and materials, as well as in the details of the illustrated construction, may be made without departing from the spirit of the invention.